# Estimating Convective Entrainment Rates Associated with Deep Convection Using Aura CO, CALIPSO/CloudSat, and AIRS Observations and Comparison with GEOS-5 Simulations

**Ryan Stanfield**[1], Hui Su[1], Jonathan. H. Jiang[1] , Lei Huang[2],
Zhengzhao Johnny Luo[3], Saulo Freitas[4], Andrea Molod[4], Ming Luo[1]

1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
2) Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, CA
3) City College of New York, CUNY, New York, NY
4) NASA Goddard Space Flight Center, Greenbelt, MD

Stanfield, R. E., H. Su, J. H. Jiang, S. R. Freitas, A. M. Molod, Z. J. Luo, L. Huang, M. Luo, Convective entrainment rates estimated from Aura CO and CloudSat/CALIPSO observations and comparison with GEOS-5, J. Geophys. Res. 10.1029/2019JD030846, 2019.

# Introduction

- Entrainment rate (λ) in convective parameterization is one of the most sensitive yet uncertain parameters that affect climate sensitivity, clouds, precipitation, and trace gases.

$$\frac{\partial \eta(z)}{\partial z} = \lambda$$

- Observational estimates of λ are often made with in-situ or field campaign data over localized regions.

- The knowledge about the characteristics of λ for global deep convective events has been very limited.

- We use the joint retrieval of carbon monoxide (CO) from MLS and TES on Aura in conjunction with CloudSat/CALIPSO deep convection data to derive deep convective λ over the globe and compare the results with GEOS-5 model counterparts.

# Data Used

**[Observations] Level 2, daily swath data**

- **TES-MLS:** combined CO profile data
- **CloudSat/CALIPSO:** 2B-CLDCLASS-LIDAR data (cloud type, cloud base, cloud top)
- **AIRS:** AIRX2RET data (relative humidity, CAPE)

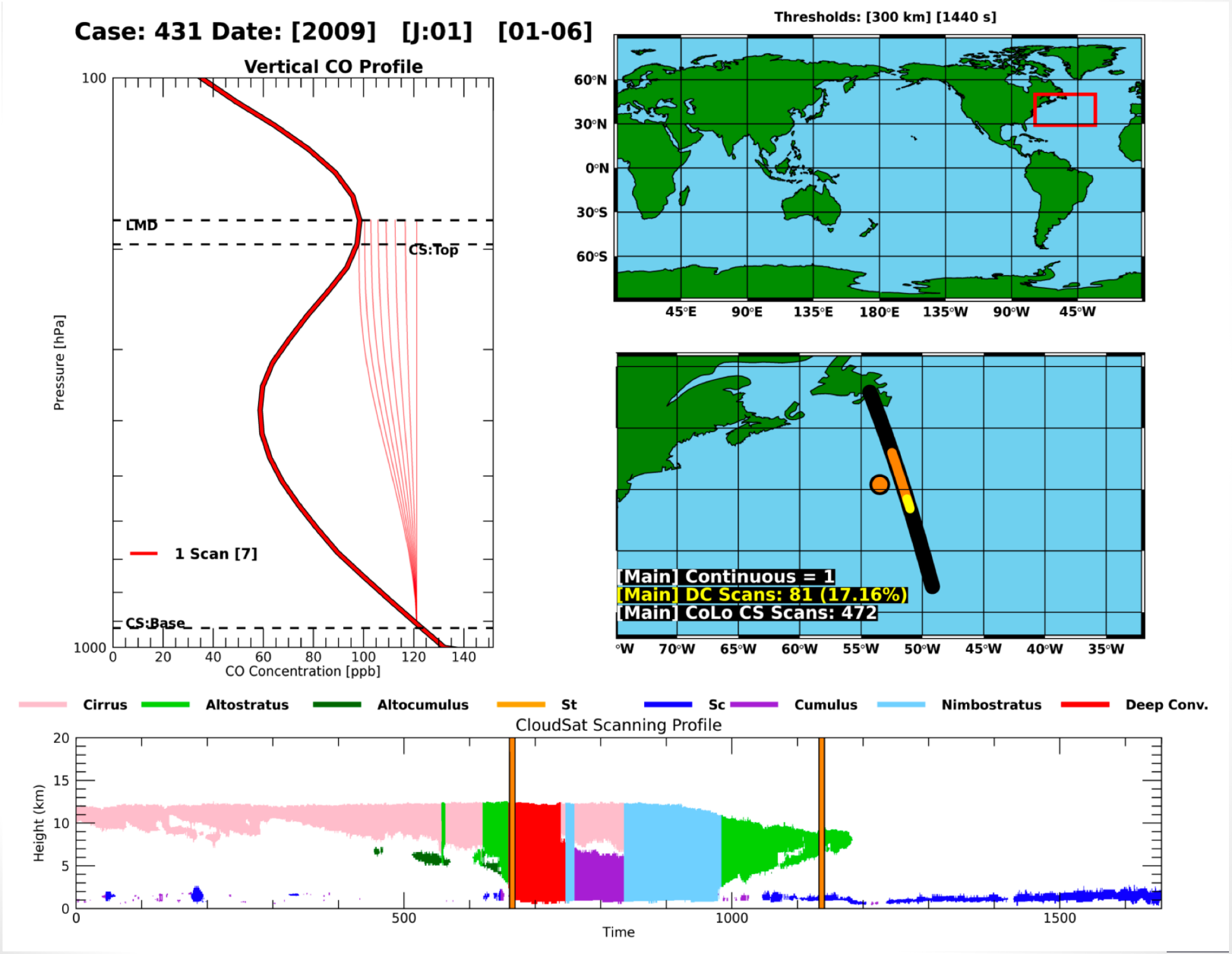
**[Model] 6-hourly gridded model output**

- **GEOS-5: 0.5º resolution, 72 layers from the surface to 0.01 hPa**

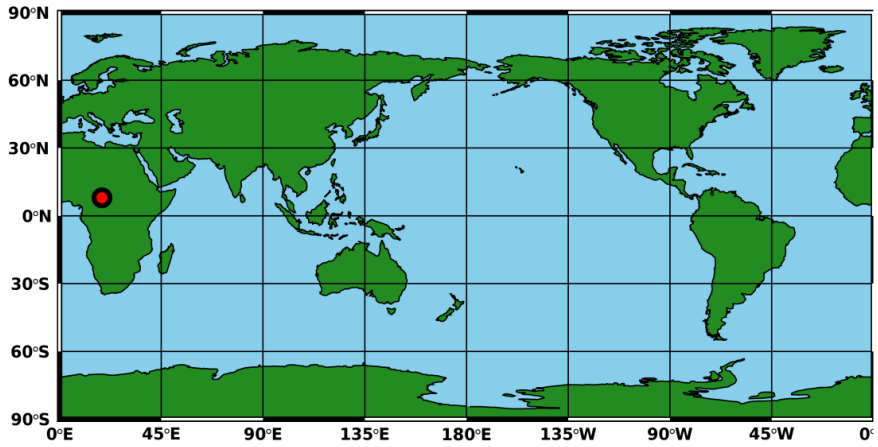
**[Time Periods]**

- Observations: 01 / 2007 – 12 / 2010
- GEOS-5: 01 / 2009 – 12 / 2009

# Methodology



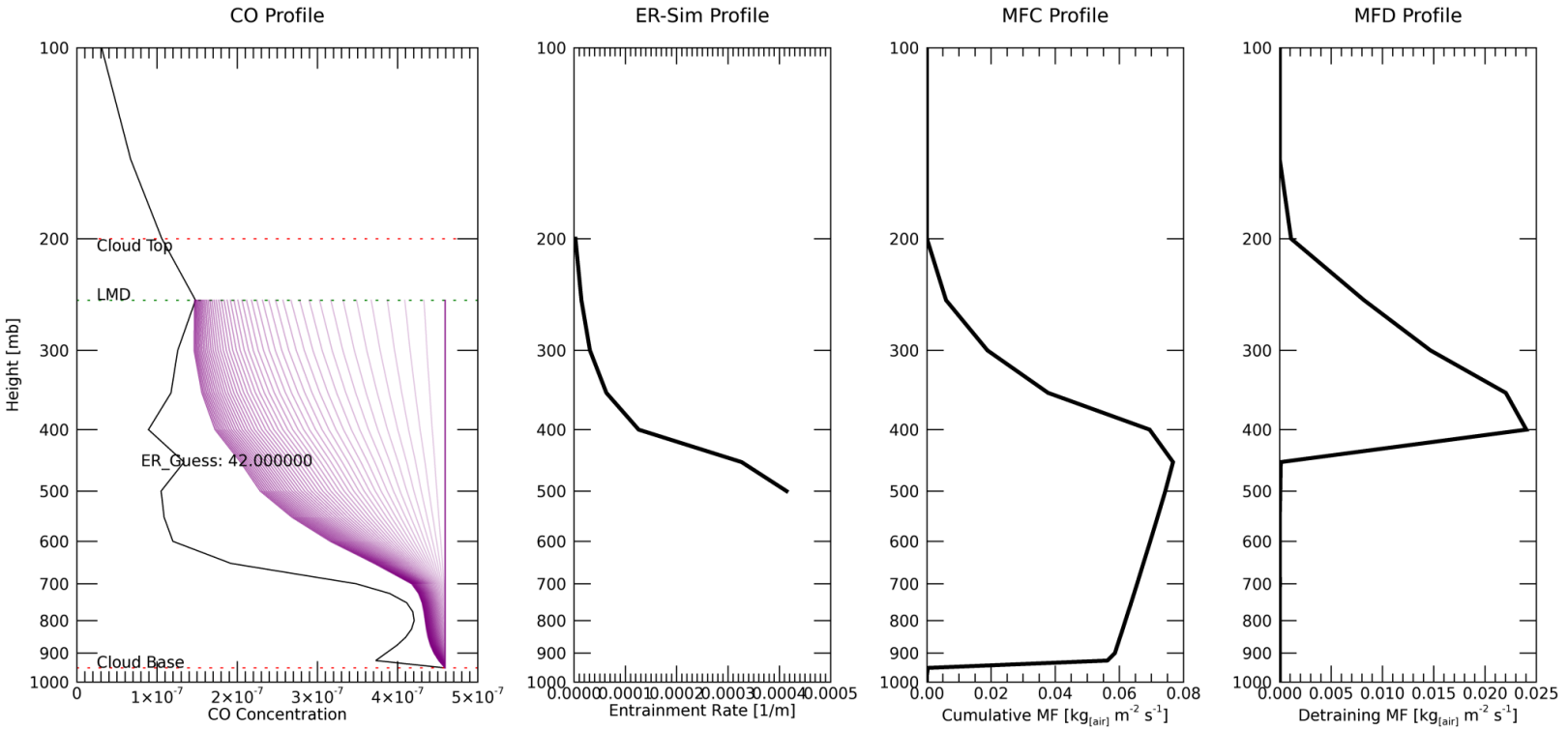
# GEOS - 5




Date: 2009/01/01
[Case = 5684 ]
[Count = 93 ]

LAT: 8.0000000
LON: 18.750000

Height [mb]




CO Concentration

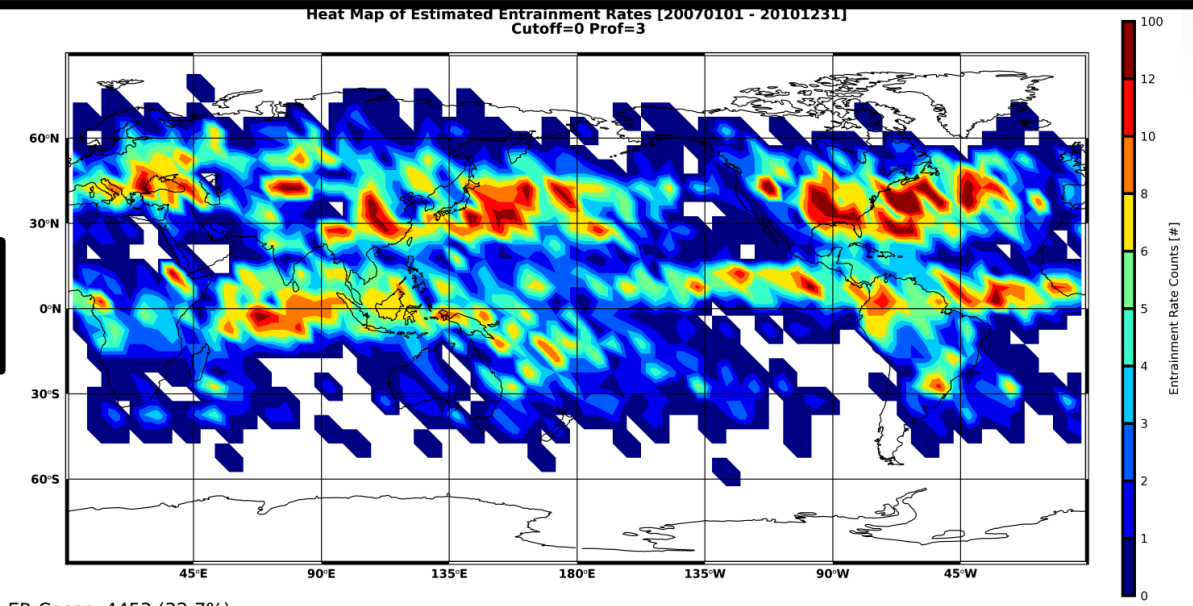
ER

Cumulative MF

Detraining MF

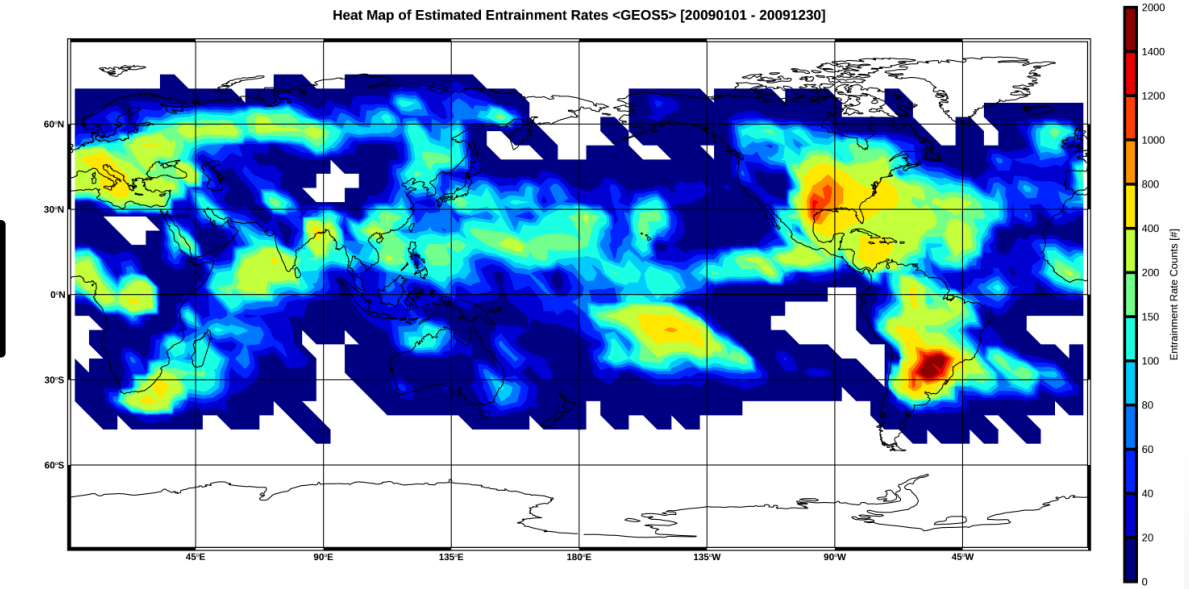
# Distribution of Valid ER Retrievals

OBS




ER Cases: 4453 (32.7%)

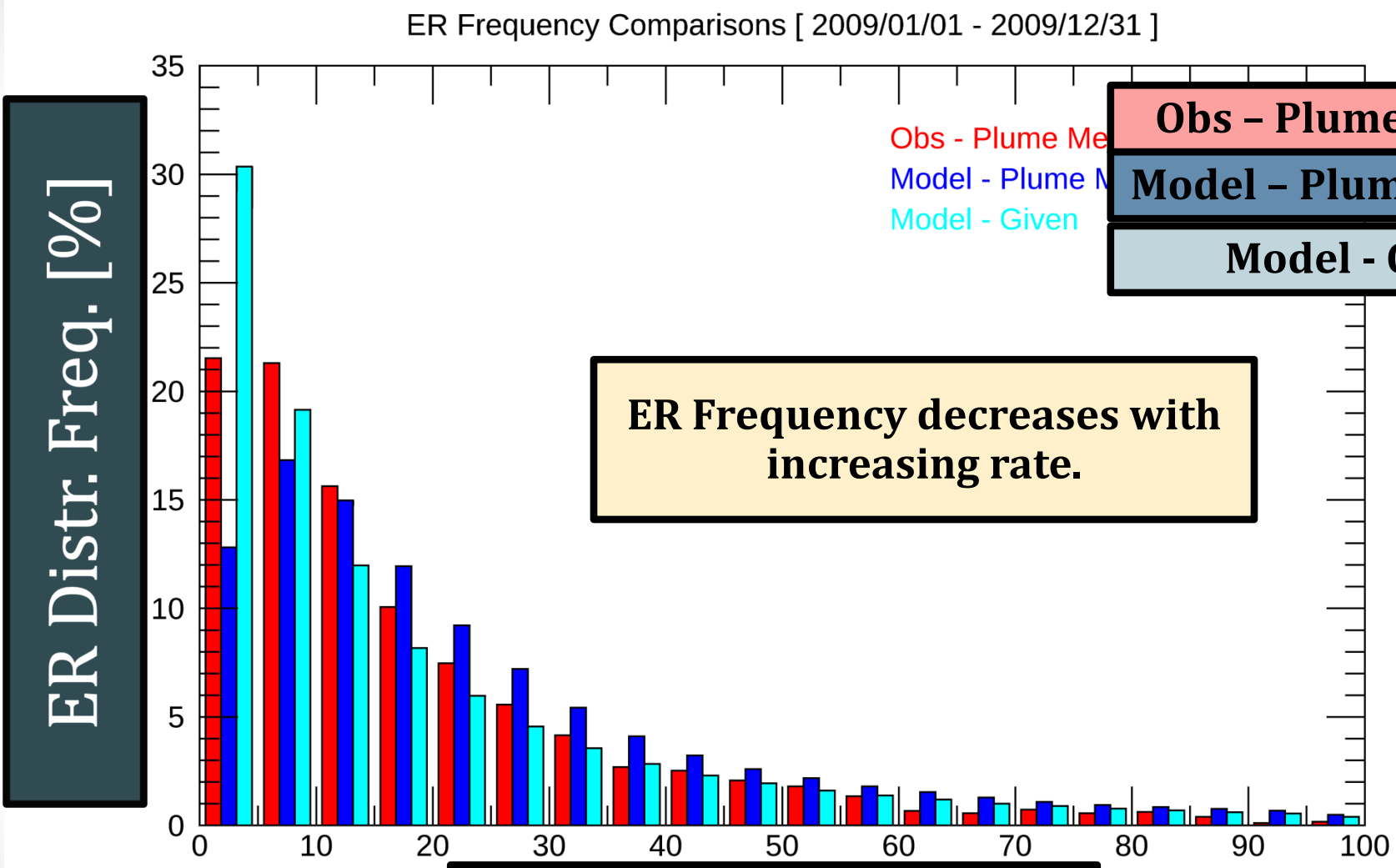
GEOS-5




ER Cases: 139475.

Grid: 5.0° (lon) X 5.0° (lat)

# ER Distribution by Method/Source




ER Distr. Freq. [%]

**Obs – Plume Method**

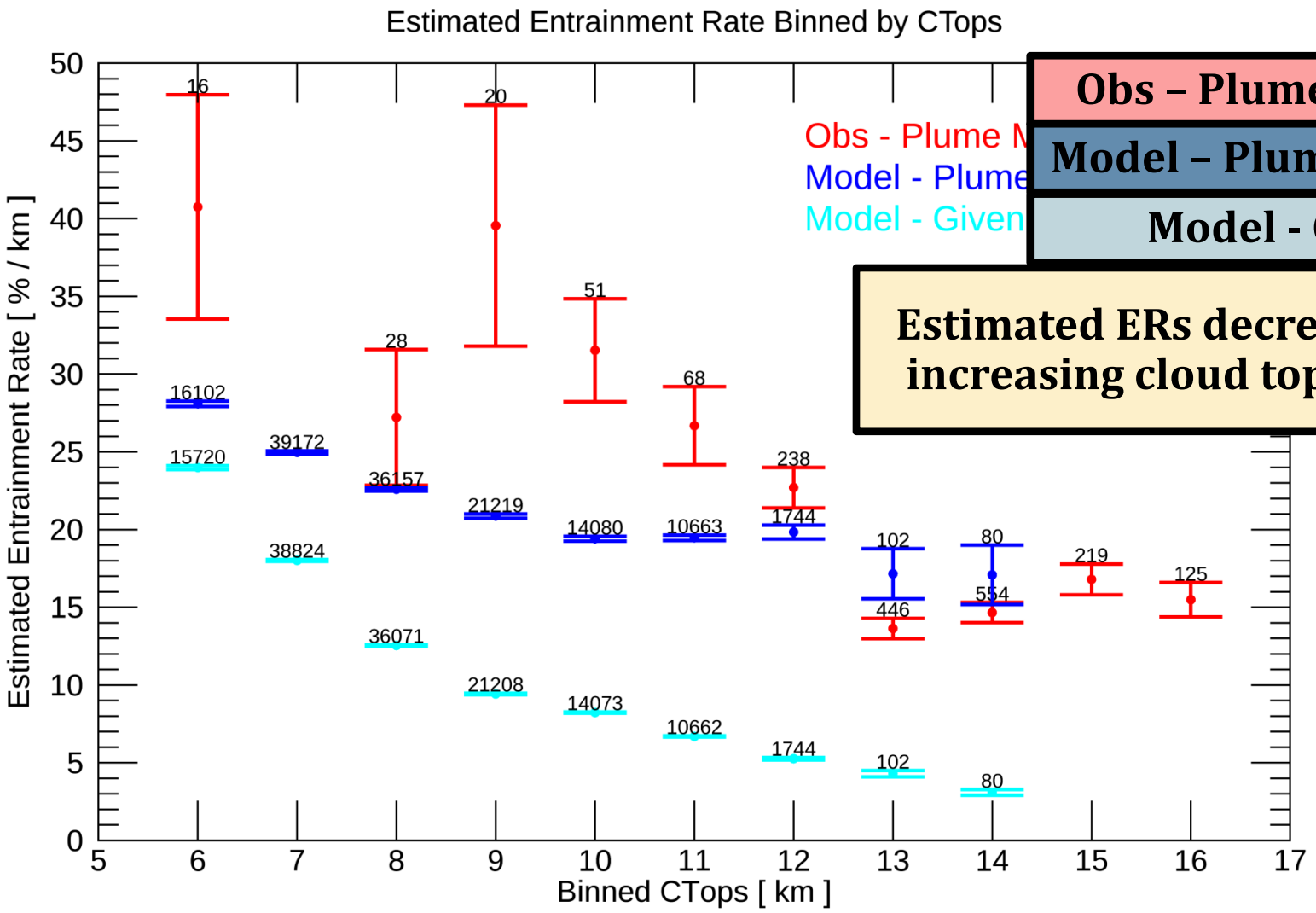
**Model – Plume Method**

**Model - Given**

**ER Frequency decreases with increasing rate.**

Estimated ER [%/km]

# ER Distribution – Binned by Cloud Top Height



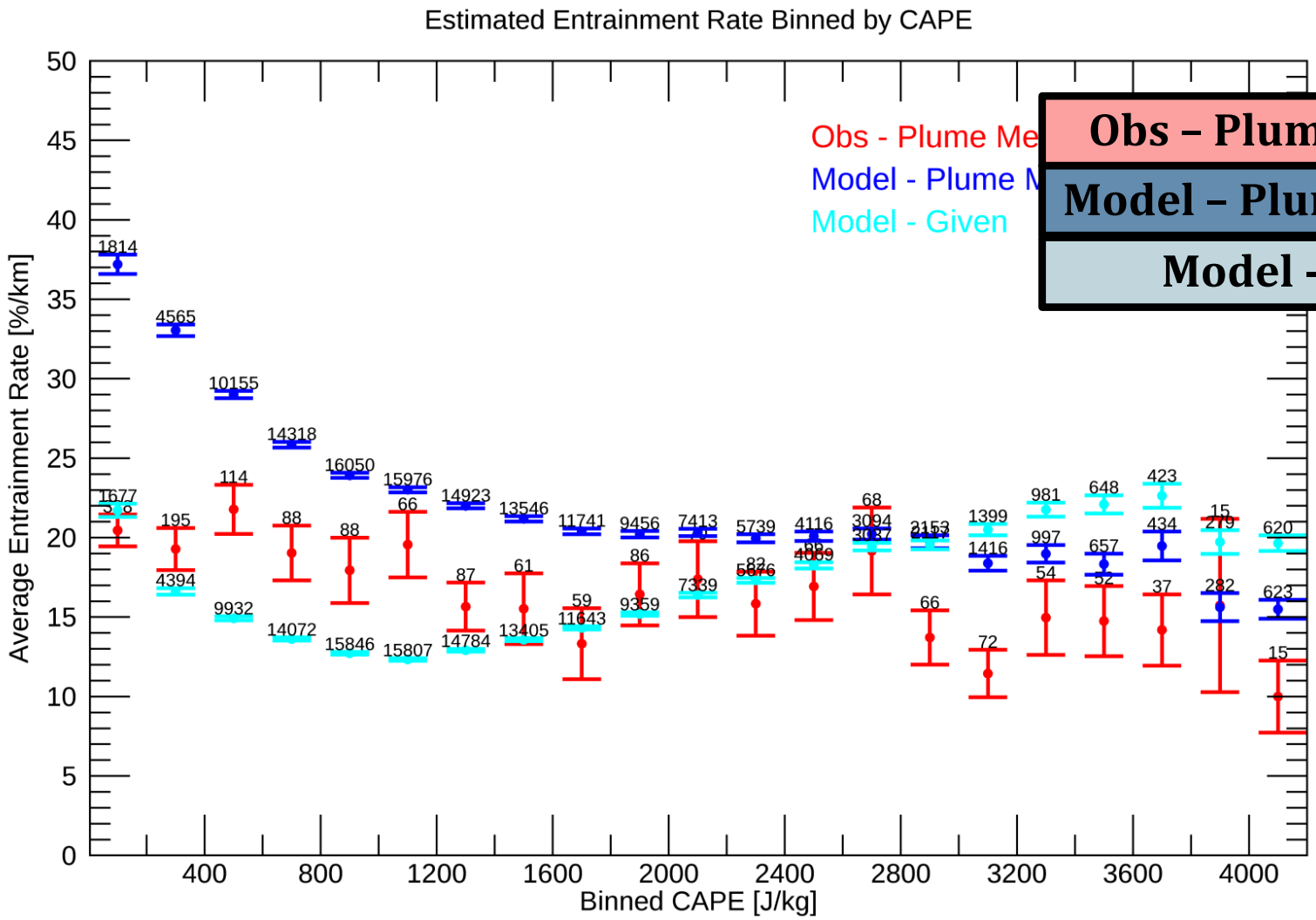

**Obs – Plume Method**

**Model – Plume Method**

**Model - Given**

**Estimated ERs decrease with increasing cloud top height.**

# ER Distribution – Binned by CAPE




**Obs – Plume Method**

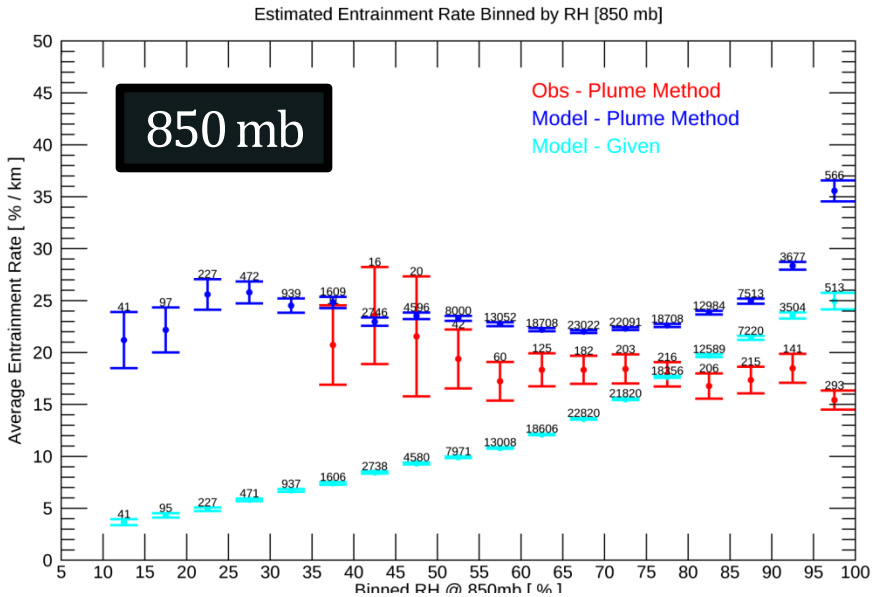
**Model – Plume Method**

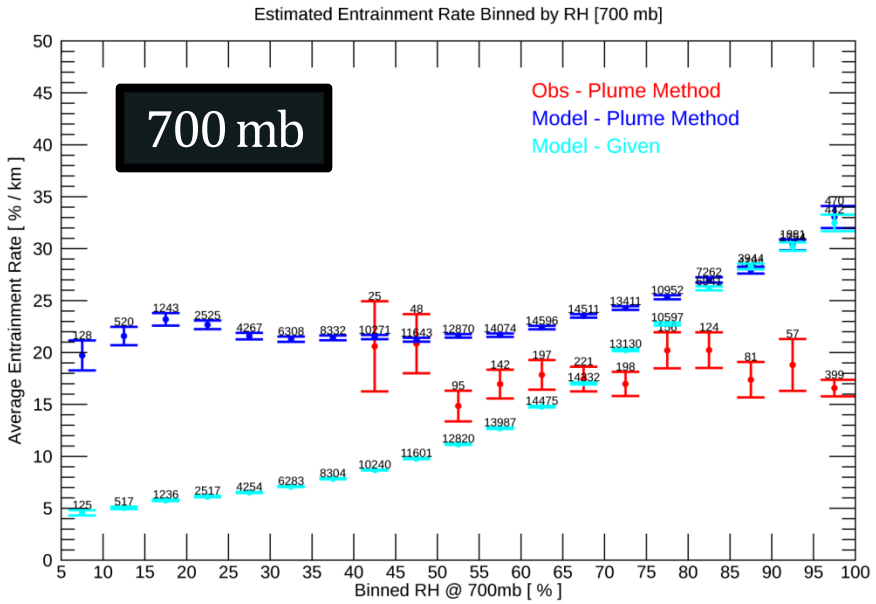
**Model - Given**

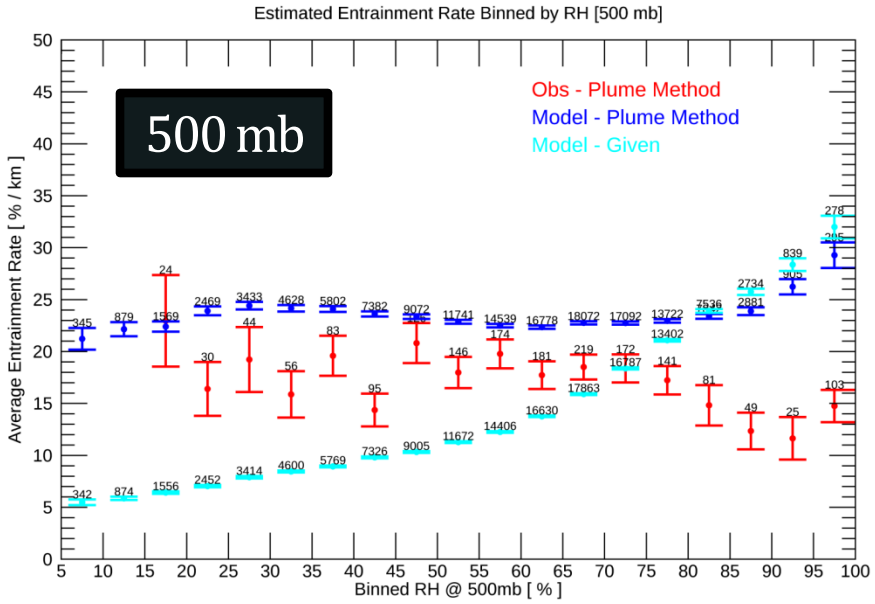


**Estimated ERs decrease with increasing CAPE using both plume methods, however, ERs used directly in the GEOS-5 model show strong decrease followed by an increase in ER with CAPE.**

# ER Distribution – Binned by Relative Humidity




**Model plume estimated ERs and given ERs increase with increasing RH, while the observation-based ER does not vary much with RH.**

**Obs – Plume Method**

**Model – Plume Method**

**Model – Given**

# Summary

- A decrease in frequency of estimated/given ER with increasing ER. The estimated and given ERs were found to be predominately below 20 %/km.
- A decrease in estimated ER is found with increasing cloud top height. GEOS-5 simulated ERS are found to be much lower especially at higher clout top heights.
- Estimated ERs decrease with increasing CAPE using both plume methods, however, ERs used directly in the GEOS-5 model shows a strong decrease followed by an increase in ER with CAPE.
- Model plume estimated ERs and given ERs increase with increasing RH, while the observation-based ER does not vary much with RH.